FURTHER EXPERIMENTS ON CORRELATION OF GROWTH IN BRYOPHYLLUM CALYCINUM

JACQUES LOEB

(WITH SEVENTEEN FIGURES)

The following note contains some additional observations on the phenomena of correlation in *Bryophyllum calycinum*. In his first

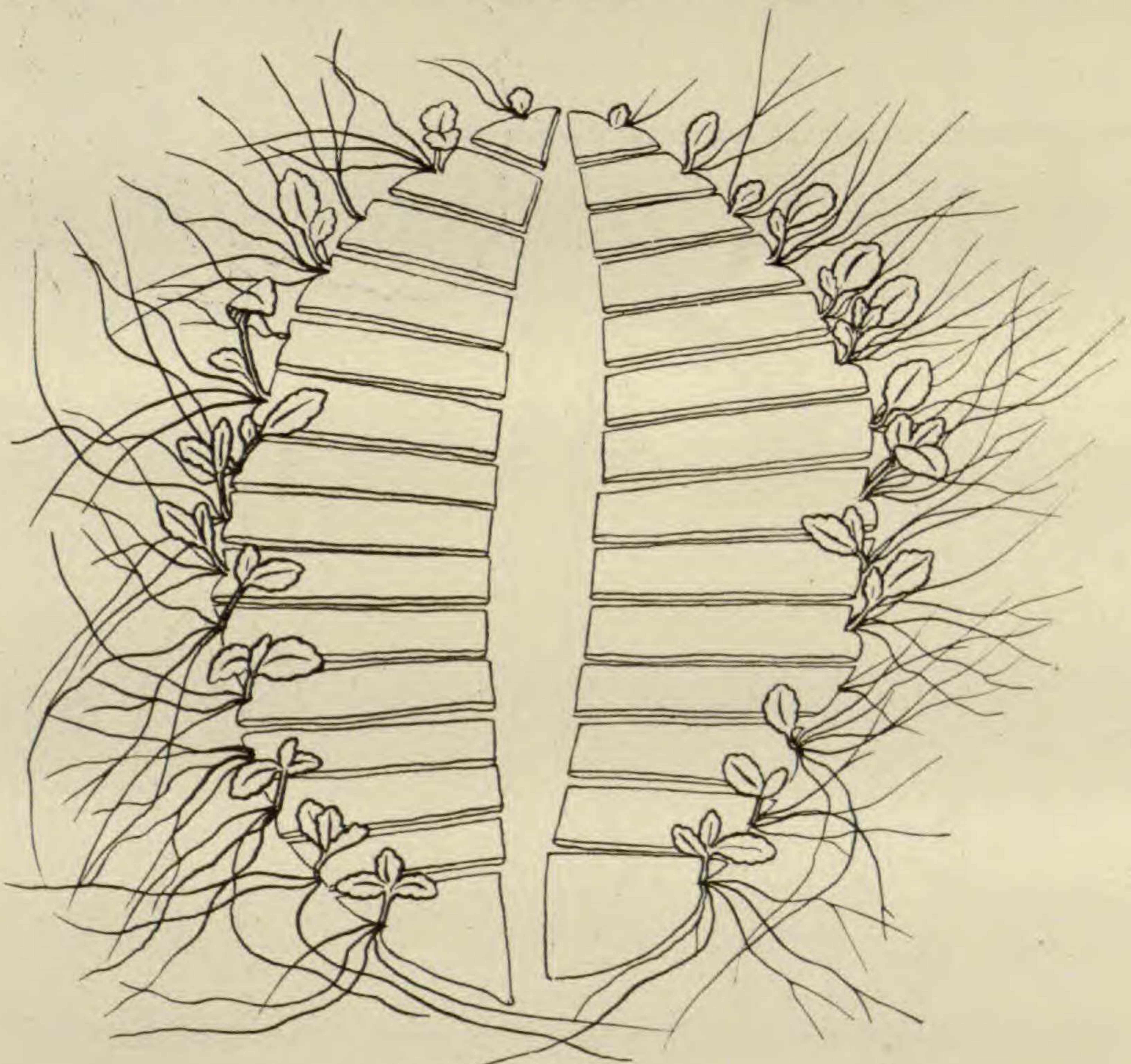
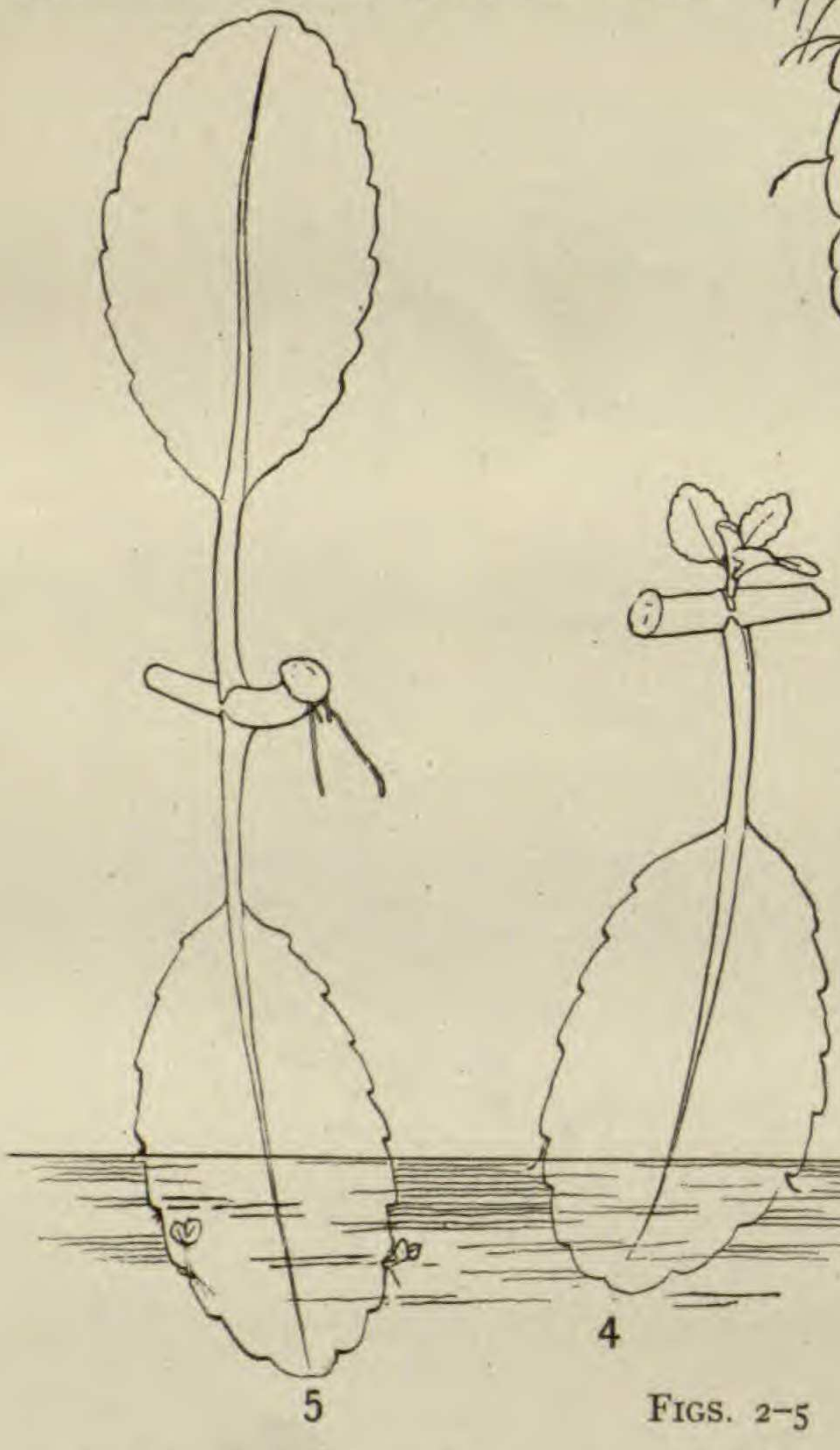


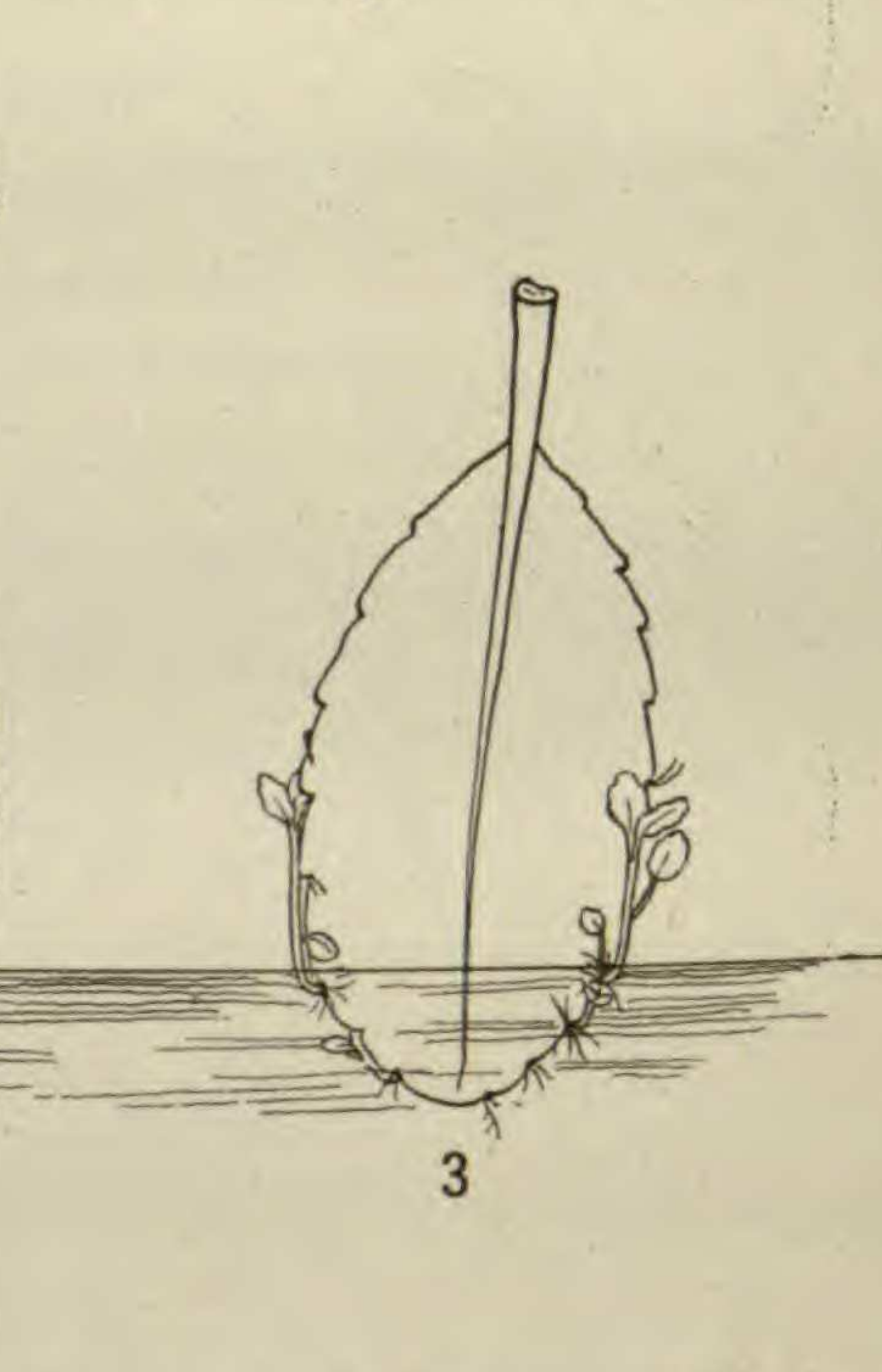
FIG. 1

note[1] the writer had reached the conclusion that a flow of certain substances away from the leaf or its notches prevented roots and shoots growing from these notches, so long as the leaf was connected

[1] LOEB, J., BOT. GAZ. 60:249–276. *figs. 41.* 1915.

with the normal plant. It is impossible to state at present whether the substances, whose flowing away from the notches prevents these from growing out, are the water or solutes (sugar, amino acids, salts, or specific substances). As soon as the leaf is cut off from the plant the flow of these substances away from the leaf ceases and the notches can grow out. This flow, the writer





FIGS. 2–5

assumes, is caused by a "suction" on the part of the growing tips of the stem or the roots, the "suction" being only a symbol to indicate the direction of the flow.

The experiment illustrated in figs. 1 and 2 never fails. Two leaves from the same node are cut off from the plant and put into sufficiently large Petri dishes containing some water. One leaf is cut into as many pieces as there are notches. Every notch gives rise to roots and a shoot (fig. 1). The other leaf is left intact and in this leaf only a few notches will grow into roots and shoots (fig. 2), but the growth is much more rapid in these new shoots than

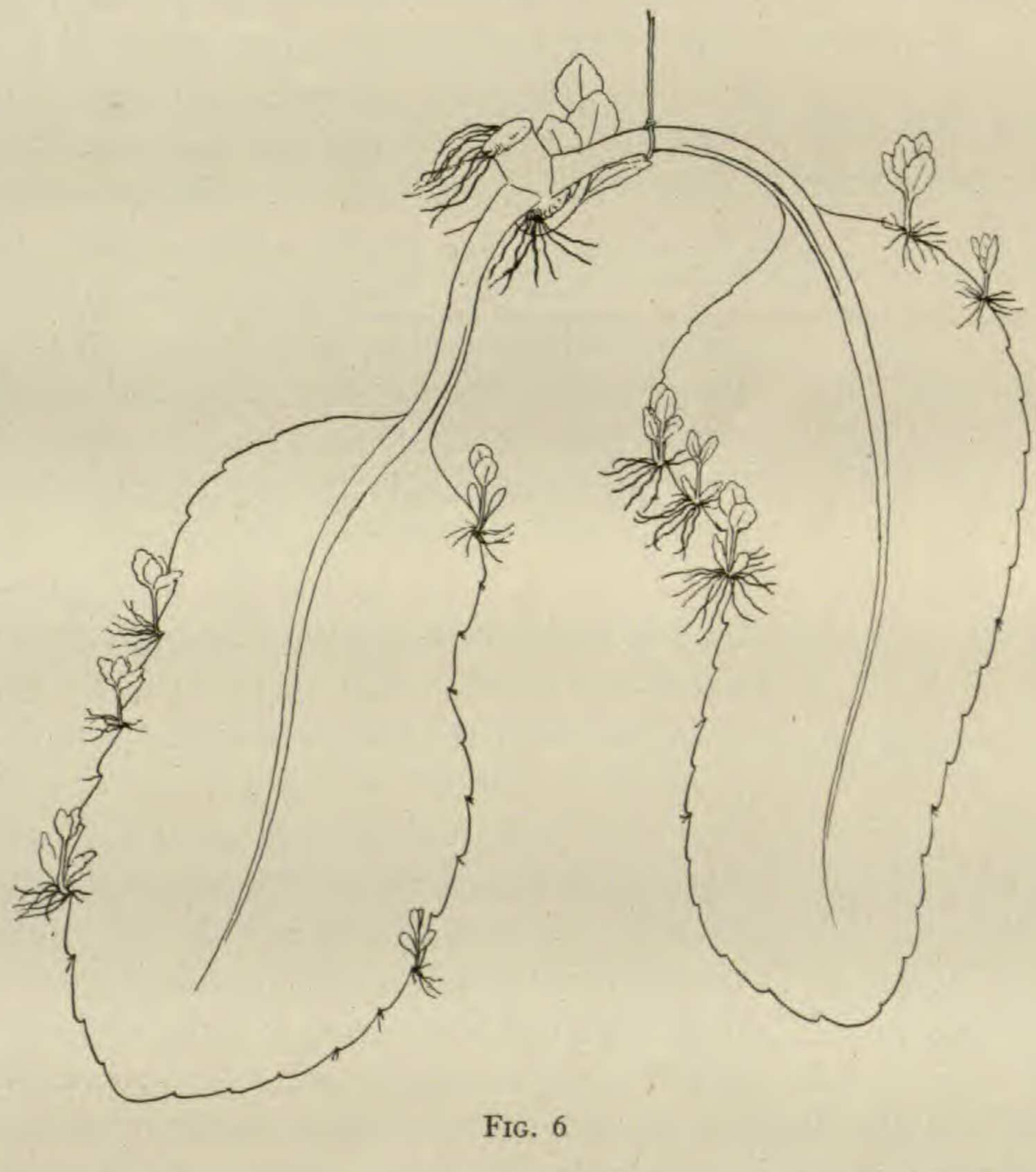


FIG. 6

in those of the other leaf. The explanation is simple enough. In the intact leaf (fig. 2) the notches which by chance happen to grow out first act as if they had a suction effect and caused the current of sap to flow away from the other notches, thus preventing their growth. This illustrates sufficiently the principle of correlation by which the notches of a leaf will not grow out as long as it is connected with a healthy plant. In the latter, the suction of the growing region of the tips of the stem and the roots causes a flow of substances away from the leaf.

In the previous paper the following experiment was described. Three leaves were submersed with their tips in water. One leaf was completely isolated (fig. 3), the second leaf had a piece of a stem attached (fig. 4), and the third piece had the opposite leaf attached in addition to a piece of stem (fig. 5). The drawing was made 25 days later. The completely isolated leaf (fig. 3) had formed two long shoots, the leaf in fig. 4 had only the two tiny roots, and the submersed leaf in fig. 5 had two short shoots. The experiment finds its explanation on the basis of the observation represented in figs. 1 and 2. In fig. 4 the bud of the stem opposite the leaf grew out before even the notches in the completely isolated leaf of fig. 3 could grow. This growth of the bud on the stem acted as a center of "suction" on the leaf and created a flow away from the notches toward the stem. Even when the growth of this bud is prevented the stem has a suction effect. In fig. 5, where two leaves were left, no shoot would grow out from the stem, and hence shoots could grow out from the immersed leaf, but not as rapidly as in the completely isolated leaf (fig. 3), showing that probably, using the symbol of a "suction," some suction must have been caused by the stem, but not as much as if the opposite leaf had not existed.

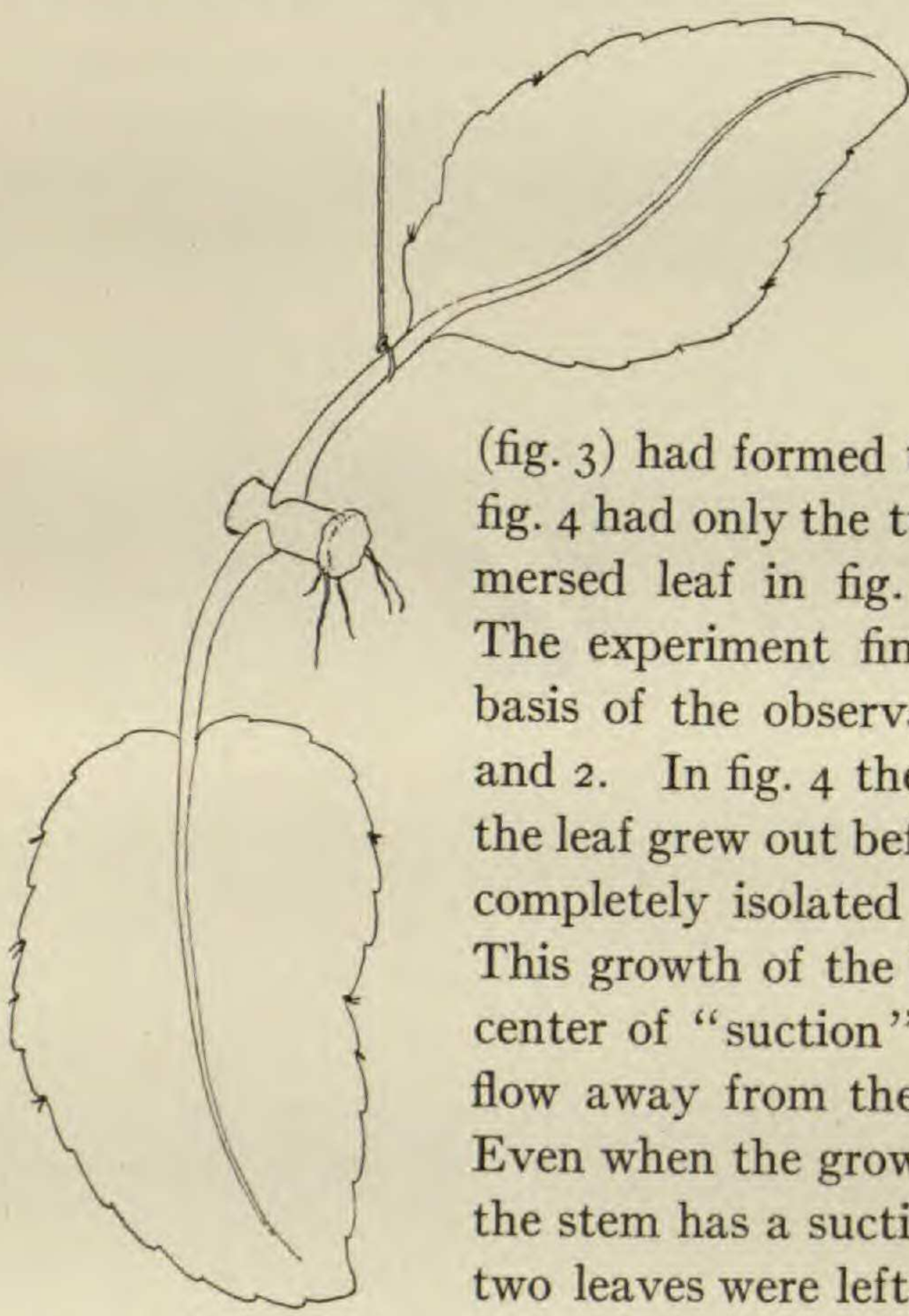


FIG. 7

The writer was anxious to see whether this experiment would not succeed when the whole leaves are suspended in moist air instead of submersing the tips in water. This latter form of the experiment has the drawback that in the leaf with a stem (fig. 4) the growth of the notches in the submersed part is often not entirely inhibited but only delayed; while if such a leaf is suspended in air the growth of the notches is generally permanently suppressed. Hence if it were possible to repeat the experiment with leaves suspended entirely in air the results should be still more striking.

It was found that if the two leaves connected by their node are large (and probably rich in sap ?) they will give rise to new roots and shoots in their notches even if suspended in air. In figs. 6 and 7 two such pairs of leaves of different sizes from the same plant were suspended in moist air. The larger leaves (fig. 6) have each formed 5 shoots in their notches, although also one of the axillary buds of the stem had grown out. This latter growth was not able to inhibit the growth of the notches. In the smaller leaves (fig. 7) no growth had taken place in the notches. The drawing was made 19 days after the commencement of the experiment. The moderate "suction" of the stem sufficed to suppress the growth of the notches in the smaller but not in the larger leaves when suspended in moist air.

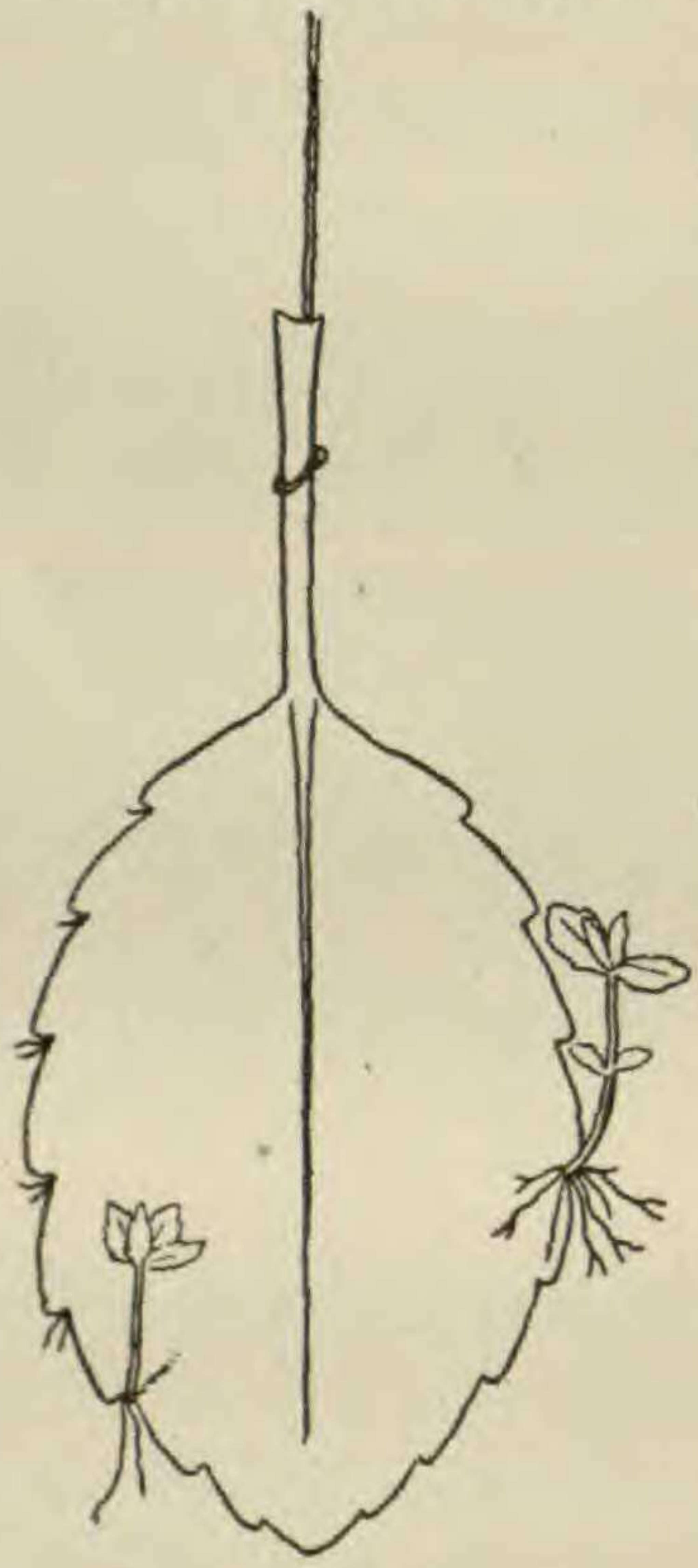


FIG. 8

Figs. 8, 9, and 10 are the replica of the experiment represented in figs. 3, 4, and 5, but with the difference that in figs. 8, 9, and 10 the leaves were entirely in air. The leaves were large and gave a characteristic result. The completely isolated leaf (fig. 8) had formed two large shoots from notches; the leaf of fig. 9 had formed neither roots nor shoots in its notches on account of the complete inhibitory effect of the piece of stem and

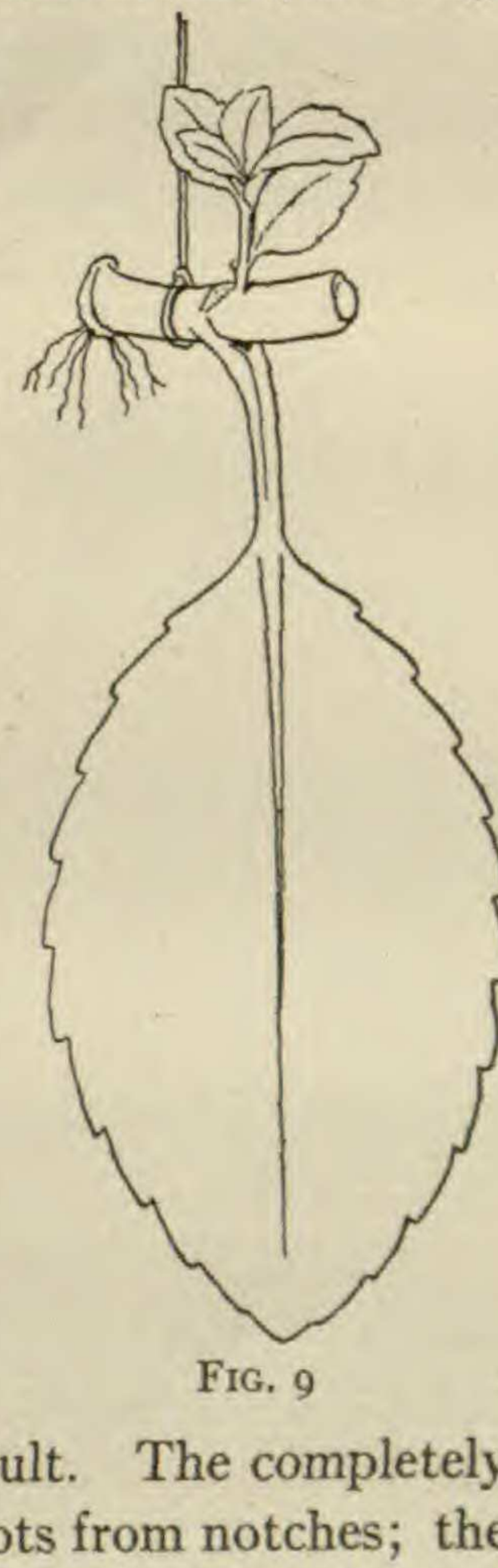


FIG. 9

its bud. In fig. 10 one shoot had been formed in the lower leaf, which had commenced to grow later than the two shoots in the completely isolated leaf in fig. 8. This drawing was made 5 weeks after the beginning of the experiment. These 3 specimens represent 3 different degrees of "suction" away from the notches of the leaf. In the leaf shown in fig. 9 the suction from the stem was too strong and no notches of the leaf grew. In fig. 10 the suction was less and one notch showed growth, which was less rapid than in fig. 8. In fig. 8, the completely isolated leaf, there was no

FIG. 12

FIG. 11

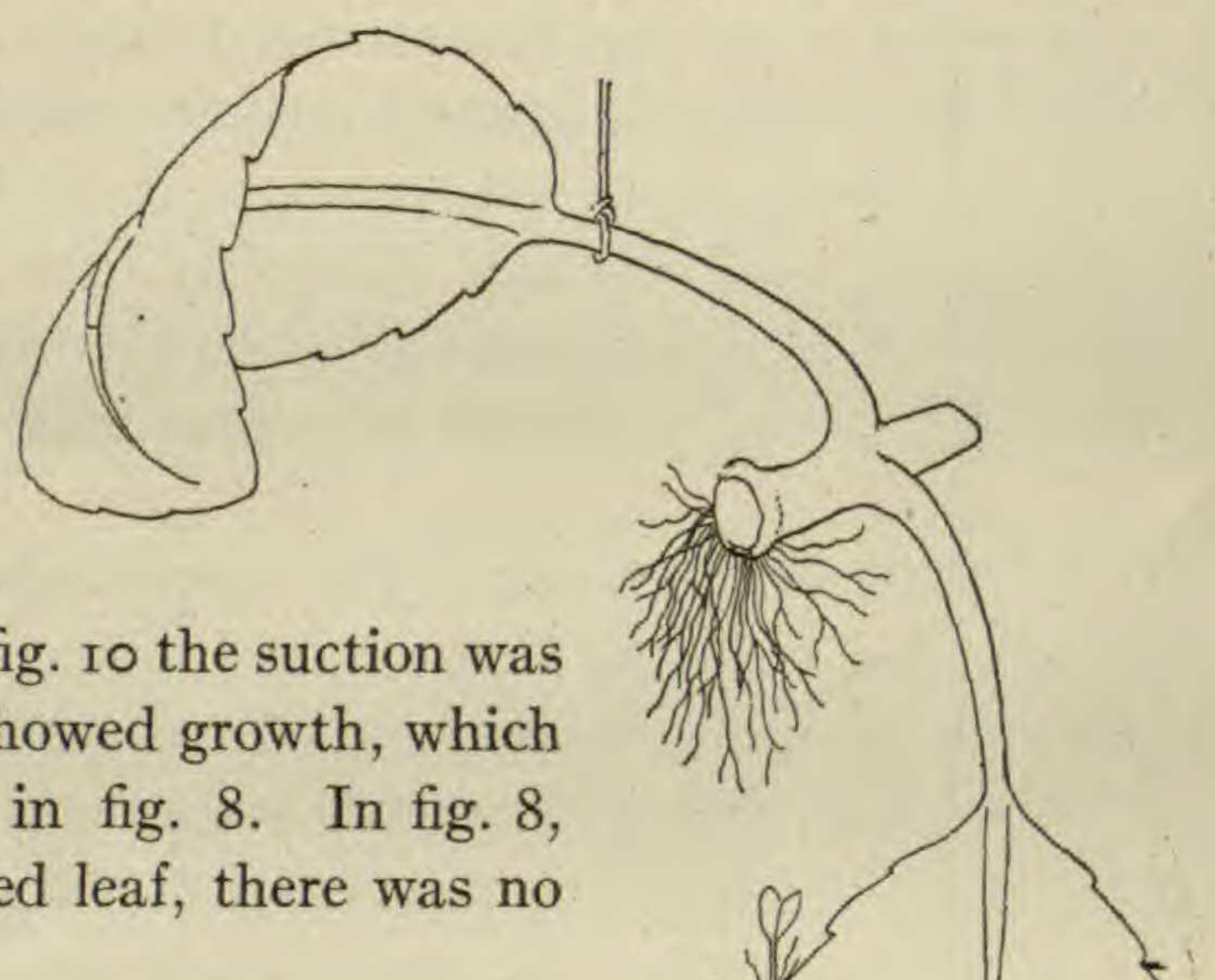



FIG. 10

"suction" away from the leaf and the growth of the notches was most rapid.

A digression is necessary to explain why in fig. 10 only the lower leaf has formed a shoot and not the upper leaf also. The writer is inclined to ascribe the phenomenon chiefly, if not exclusively, to the influence of moisture. The specimens were suspended in a glass trough loosely covered with a glass plate and whose bottom contained a layer of water. The air surrounding the lower leaf was more completely saturated with water vapor than that surrounding the upper leaf. To settle this question control experiments were made in which both leaves were equally near the water (fig. 6); in this case both leaves formed shoots, while when they were suspended higher up in the trough neither formed roots and shoots. Both

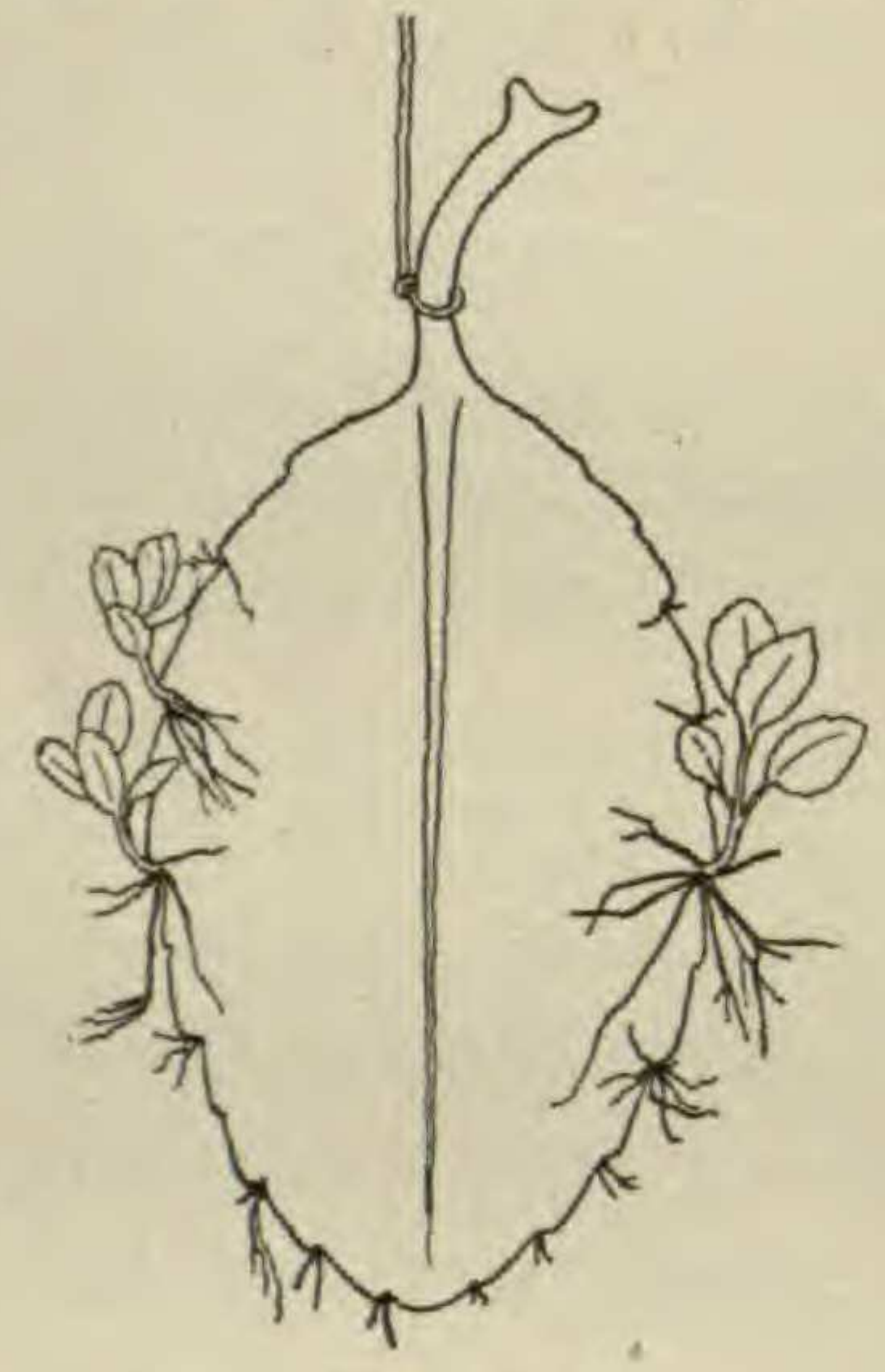


FIG. 13

leaves also formed roots and shoots when put horizontally into the water. The influence of moisture upon the growth of roots and shoots in the notches was very striking in all these experiments. Thus contact with the wall of the trough, where a condensation of water kept some of the notches moist, would favor the growth of roots and shoots in these notches.

It has been stated by previous writers that in a completely isolated leaf of *Bryophyllum* the notches grow out because the stalk of the leaf does not form roots. This statement is not strictly correct, as has been stated already in the first article. An example was given in fig. 16, p. 261, where a leaf formed roots and shoots in one notch although roots and a shoot had been formed on the stem, owing to the fact that the piece of the axillary bud was still in contact with the stalk of the leaf. We must assume that in this case the suction from the new growth at the stalk of the leaf was less than if a piece of stem had been there, and this lessened suction permitted one notch of the leaf to grow into a shoot. It occurred to the writer that this assumption might be put to a test. Leaves were

FIG. 14

prepared being connected by a piece of the cortex of the stem, without the wood (fig. 11), and the behavior of such leaves was compared with the behavior of leaves which were attached to a complete piece of stem (fig. 12). Both sets of leaves were suspended in moist air. Leaves of the latter type (fig. 12) never formed shoots in their notches, and at best only a beginning of root formation was noticeable, which never led to roots longer than 1 mm. The bud on the stem opposite the leaf grew out into a vigorous shoot (*S*), and at the lowest point of the callus of the stem, roots (*R*) were formed.

The other type of leaves with only a piece of cortex attached (fig. 11) formed always numerous long roots and quite frequently shoots, while the cortex formed roots (*R*) at the basal end and small leaves (*L*) from the axillary bud of the leaf. The drawing was made after 5 weeks. The growth of the roots and shoots at the cortex did not inhibit the growth of the notches, since in our assumption the suction which the cortex produced was not as strong as if the piece of stem had been complete.

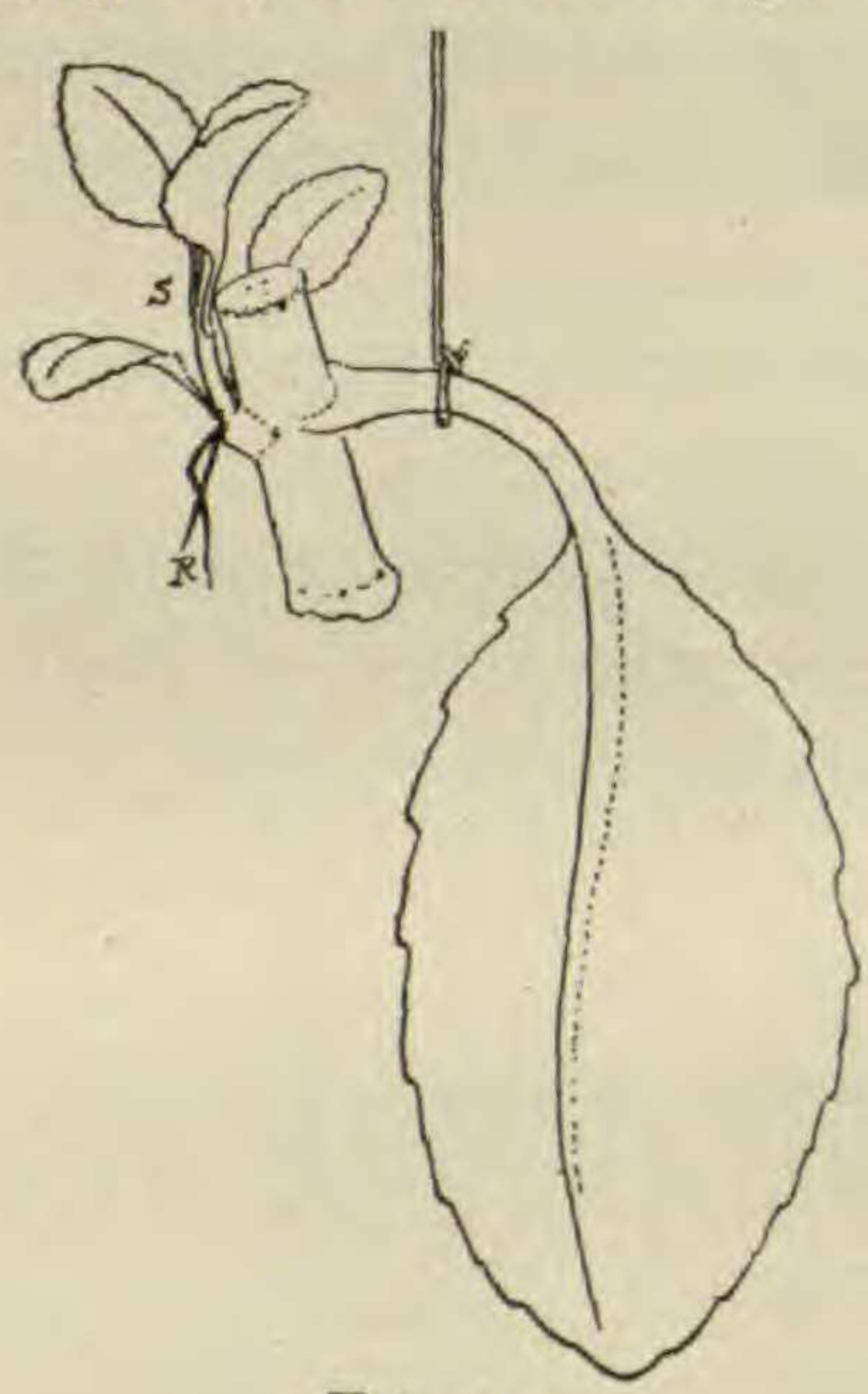


FIG. 15

This furnishes us, therefore, with a method of retarding the velocity of the flow away from the notches of the leaf without interrupting it completely (as in a completely isolated leaf) or without making the flow too strong, as is the case when a whole piece of stem (without the opposite leaf) is attached (as in fig. 12). This difference should find expression in the relative velocity of growth in the notches if the proper experiments were made. Figs. 13, 14, and 15 represent such a series, 3 weeks after the experiment was begun. The leaves were suspended in moist air. The completely isolated leaf (fig. 13) has formed 3 shoots of more than 1 cm. in length and roots of considerable size. The second leaf with a piece of cortex attached (fig. 14) has roots and only one short shoot in the notches, but has a considerable shoot and roots in the cortex. The flow of sap from the leaf to the cortex was not strong enough to completely prevent the growth of the notches, but only to retard it. The third leaf (fig. 15) has a piece of complete stem attached and in this leaf no growth has taken place, and in all probability none will take place in the notches. Instead a strong shoot (*S*) has been formed from the axillary bud of the leaf which had been removed. The "suction" effect of the complete stem or of the growing bud was strong enough to inhibit the growth in the notches of the leaf completely.

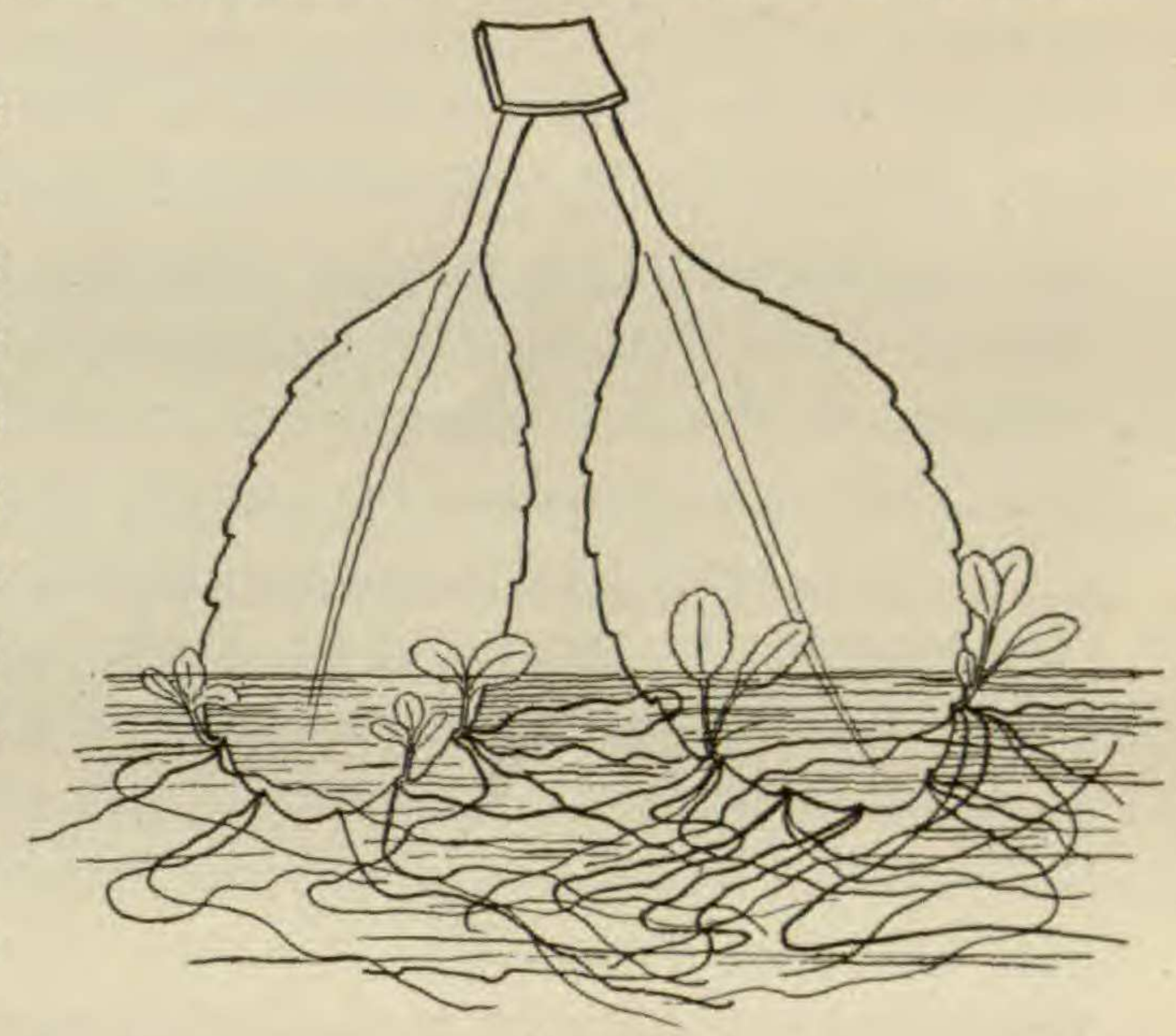


FIG. 16

All these statements can easily be verified. Some variation is met in specimens of the type of fig. 14, inasmuch as very often only the roots will grow out from the notches, while the shoots will not develop beyond tiny beginnings.

In all the experiments we have thus far described the suction effect of the stem inhibited the growth of the notches of the leaf. If the theory be correct that it is only the sap flow to or from a dormant bud which determines whether the latter will grow or continue in a resting condition, the reverse experiment should also be possible; namely, that by accelerating the growth of notches in a leaf it should be possible to inhibit the growth of buds on the stem. From all that has been said this experiment could only meet with success where the suction effect of the stem is moderate. Two leaves of the same node are cut from the plant, the cortex of the piece of stem is cut lengthwise and the wood taken out from the stem (fig. 16). This leaves two leaves connected only by the cortex of the stem (fig. 16). The leaves are placed with their tips under water to induce a rapid growing out of the notches at the tips of the two

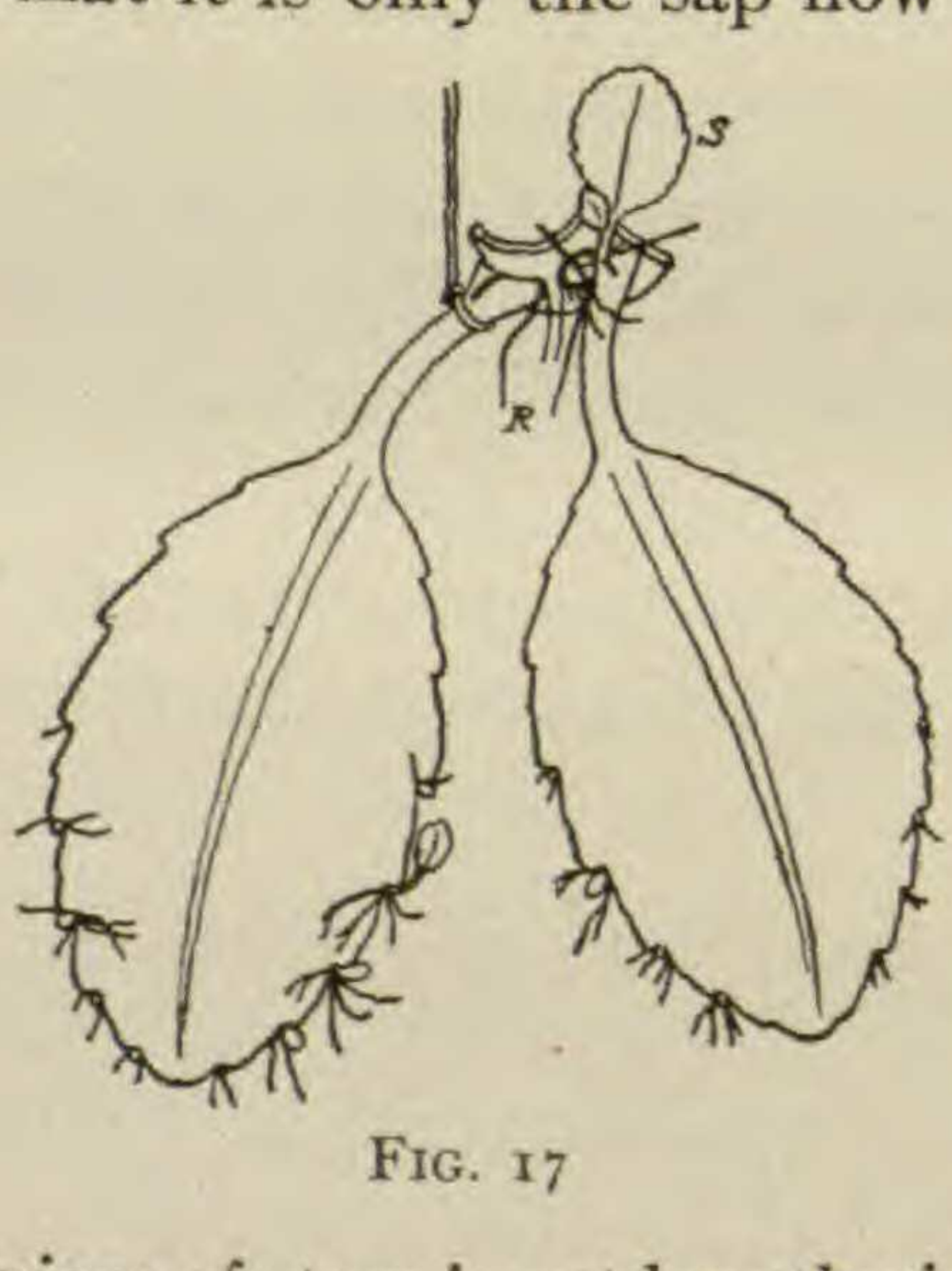


FIG. 17

leaves. Other leaves of the same plant are suspended in moist air (fig. 17). Figs. 16 and 17 were drawn after 22 days. The leaves suspended in air (fig. 17) had formed vigorous roots (*R*) and a shoot (*S*) at the cortex. The leaves themselves had formed, as usual in this case, numerous roots and some tiny shoots. The notches of the leaves suspended in water (fig. 16) had formed very powerful shoots and roots and this inhibited the growth of roots and shoots in the cortex. Needless to say, these experiments were all carried out on many specimens, as were all the experiments reported in this and the previous paper. The experiments show that a vigorous growth in the notches of a leaf can act as a center of "suction" which may prevent the flow of sap to the cortex and thus prevent the growth there, if the suction by the stem, or in this case the cortex, is not too strong.

If the whole piece of the stem is left with its two leaves instead of the cortex alone, the experiment may also succeed, but it is not so reliable since the suction of the stem is greater in this case. If the experiment is made with one leaf and a complete piece of a stem and the leaf is put partly in water, the leaf cannot suppress the formation of the shoot on the opposite side of the leaf, since the suction effect of the stem cannot be overcome by the leaf. But when we have only a piece of cortex instead of a piece of complete stem (with wood), the "suction" power of the cortex alone is less than that of a complete piece of stem, and hence can be suppressed if a vigorous stream of sap to the growing notches of the leaves is started, as is the case in fig. 16.

It is hardly necessary to state once more that the term "suction" effect of a growing notch or bud is used only to illustrate the direction and relative velocity of the flow.

Rockefeller Institute for Medical Research
New York City